# ISSUES IN HIGHER EDUCATION IN SCIENCE

INDIAN NATIONAL SCIENCE ACADEMY
Bahadur Shah Zafar Marg, New Delhi

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# PREFACE

An important role of the Academy is to take up major national issues related to science and technology for discussion and come out with reports based on objective examination. Such reports of the Academy need not necessarily represent the views of all the Fellows. Yet, they would serve the important purpose of providing impartial advice on crucial matters of national importance. It is also not necessary that such reports be totally accepted by policy makers and the Government. However, any enlightened administration should certainly give serious consideration to reports published by the Academy. I am deeply conscious that we have not done enough in this regard and we have to make a beginning. I urge the Fellowship to contribute their mite in making this possible and help the Academy in becoming more visible in the scientific scene in the country.

As a beginning in this direction, the Academy organized a mini-symposium on 'Issues in Higher Education in Science' on September 30, 1985. A few papers had been prepared in advance of the meeting. Based on the discussions in the symposium and suggestions received from fellow scientists, we have arrived at certain recommendations which may be of some value. In this brief report, we present the proceedings along with the pre-symposium papers. I realise that it is difficult to be entirely original in making recommendations related to the educational system. I, however, hope that this report will be found useful by scientists, educators, planners and administrators.

I am thankful to Professors R R Daniel, H Y Mohan Ram and P N Tandon for their valuable help in editing this report.

C N R RAO
President
Indian National Science Academy

# ISSUES IN HIGHER EDUCATION IN SCIENCE

## Introduction

The Fellowship of the Indian National Science Academy (INSA) has been concerned for some time about the state of science and science education in the country. Discussions on this subject have been held on several occasions in the last few years and there is full awareness of the various national efforts made in this regard, for example, the reports of the Radhakrishnan Committee and the Education Commission chaired by Professor D S Kothari. Recently, the Prime Minister has expressed an urgency to change our education system to make it more responsive to the needs of the people. Following this, the Ministry of Education released a document entitled "Challenge of Education—a Policy Perspective" in August 1985, and the Union Minister for Human Resource Development has invited a nation-wide debate on this document to facilitate the formulation of a new education policy. It was, therefore, considered appropriate for INSA to give due consideration to issues relating to higher education in science and scientific research. With this in mind, a mini-symposium was held at the INSA premises in Delhi on 30th September 1985, which resulted in an in-depth examination of the subject. Following this, additional consideration was given by INSA and it was decided that a brief document be prepared and submitted to the Ministry for Human Resource Development to convey its input to the national debate. This document addresses itself only to higher education in science and scientific research.

In this era of explosion of science and technology, it may appear somewhat redundant to emphasize the need for improving and strengthening our science education.

In his Discovery of India, Pandit Jawaharlal Nehru emphasized that "It was science alone that could solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people".

Presenting the Government of India Scientific Policy Resolution to the Parliament in 1958, Pandit Nehru stated, "It is an inherent obligation of a great country like India with its tradition of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today".

C V Raman, one of our greatest scientists stated, "There is only one solution for India's economic problems and that is science and more science and still more science".

Homi Bhabha, the father of Indian atomic energy programme, in his address to the International Council of Scientific Unions remarked: "What the developed countries have and the underdeveloped lack is modern science and an economy based on modern technology. The problem of developing the underdeveloped contries is therefore the problem of establishing modern science in these and transforming their economy to one based on modern science and technology. An important question we must consider is whether it is possible to transform the economy of a country to one based on modern technology developed elsewhere without at the same time estabilishing modern science in the country as a live and vital force. If the answer to this question is in the negative—and I believe our experience will show that it is—then the problem of establishing science as a live and vital force in society is an inseparable part of the problem of transforming an industrially underdeveloped to a developed country".

While these statements are as relevant today as when they were first stated, problems of national development have assumed greater dimensions and complexity, and call for not only a restatement of our conviction but also pose a challenge for appropriate action.

The country can be justifiably proud of the achievements in agricultural production, atomic research and space applications, but there is a growing concern that the scientific temper has not percolated to the common man. Our new educational policy must aim at fulfilling this need. Apart from leading to natural knowledge and intellectual attainment, science education must also provide a sound and broad base to develop and support self-sufficiency and in general lead to science application and technology for improving the quality of life for our people. Finally inspite of the rapid and quantitative increase in science and scientific manpower or probably because of it, quality has been a victim all round. While preparing for the 21st century, it is imperative that steps be taken to encourage, nurture and strengthen quality at every level which is essential for solving major problems of the country and provide it a respectable place in the community of nations.

### The Present Scenario and Some Recommendations for Improvement

The present state of higher education in science including scientific research has been a subject of much debate and discussion in the past. Therefore, what will be discussed here are items that have either been not discussed much in the past or those that need to be emphasized again

because of their importance. Much of what we say here of science will also hold for engineering and technology. Some of the observations and suggestions will apply to all branches of higher learning.

1. The foundation for higher education and research is to a great extent laid in the school education. Therefore, every effort should be made at the school level itself to introduce students to the value of the scientific method which would require an enquiring mind, the need for honesty and objectivity in one's work and motivation to work hard intellectually and physically to realise one's objectives and goals. However, barring some exceptions, most of our schools are ill-equipped and poorly staffed to build such foundations. While it is necessary to provide school education to all, it is also desirable to select some existing good schools and strengthen them or create some new ones not only to act as models but also by distributing them all over the country to provide opportunity to more students, particularly those from the rural and less developed areas; this will also lead to discovery of talent from the large gene pool of the country. It is essential that merit is the main consideration for admission to these schools. Outstanding students discovered at the school level must be able to continue higher education through suitable incentives.

2. It is clear that since Independence, inspite of the quantitative increase of science and of science graduates, quality has been a victim; a larger, improved science base has, however, been established. Sometimes under the banner of equality and democracy, circumstances operate powerfully against the development of excellence. Therefore, one of our foremost concerns should be to protect, encourage and enhance the quality of work and thought which will raise the average level of science and produce leaders of excellence who can contribute to national endeavours. If we are to promote and nurture quality, it is essential that (while at the 10 + 2 level education must be open to all) at the college and university level and particularly at the MSc and PhD levels, admission must be highly selective. It will greatly help us in providing selective admission to higher studies if the vocational training at the +2 level is made more serious and goal-oriented. It will then siphon out a large fraction of our students to productive occupations without striving for university education. As a developing country on the march to development, we have a supreme but challenging goal to elevate the country to a level at par with, if not to excel, the advanced countries of the world. A driving motivation to achieve this goal must be communicated to our students in every possible way.

3. Quality and excellence become possible when we have the right person for the right job. In order to do this, it is necessary to have

periodic aptitude tests conducted to evaluate the intrinsic abilities and inclinations of each student—where strengths and weaknesses lie. This information must be used by experts in vocational guidance to communicate to the individuals about their aptitudes and guide them appropriately to choose their future.

4. A sense of belonging to the society and the nation needs to be nurtured among the students; they should also be helped to acquire an awareness to the real life problems of the country. Among others, one step to do this would be to require all students obtaining a Bachelor's degree (or a Master's degree) to give extension service for at least one year. This must be meshed in appropriately with other national programmes so that it contributes to national development. In order to make this programme successful, suitable steps must be taken to give the students interesting assignments and suitable facilities and amenities.

5. Knowledge in science and technology is growing explosively. In order to cope with this, it is necessary to revise curricula periodically. However, if we become over-enthusiastic, we may load our young people by making them memorize information and undermine their creative and enquiring faculties. This problem is likely to become more acute as time passes by and more and more knowledge is gathered at an ever increasing pace. Our efforts should therefore be to strike a right balance between acquiring knowledge and using that knowledge to acquire more knowledge or use it productively. This requires careful planning of our teaching methods and curricula. Problem-solving and project approaches are examples to promote individual thinking and objective evaluation.

6. At the level of higher education and research in science, there is a great need for mobility of teachers, researchers and students in the country. On the other hand, the recent trend is strongly towards localization. This is due to a variety of reasons such as existing rules and regulations governing such movement and a sense of regionalism. These impediments must be removed and greater encouragement given in various ways. Greater mobility within the country for the academics and students can lead to greater cross-fertilization of ideas, reduce brain drain and contribute to national integration.

7. The situation with regard to the examination system in the universities has been justly criticised by people from all walks of life. The situation is already alarming and if allowed to continue for more time will have disastrous consequences. The importance given to the marks obtained by students either for admission to higher courses or for selection for jobs has resulted in a marks-based value system that has encouraged rackets to manipulate and pressurize the whole educational system. Combined with

this, the vying of universities to jack up their marking system to compete with good universities without caring for the standards is another source of alarm. Considering the complexity of this problem, UGC and CSIR are holding national examinations to assess the real ability of students for awarding research fellowships at the Ph D level.

We also hear about the possibility of delinking degrees from jobs. Some immediate remedial action is needed; such action combined with selective admission is likely to yield desirable results. Our universities are straining under the burden of holding examinations at the graduate level. The possibility of this being shouldered by another suitable mechanism must be examined.

8. Yet another reason for the present state of affairs in the field of higher education is the lack of harmonious working of the Central Government, State Governments and the UGC. There are too many instances of external interference or pressures on the university system. Even political parties bring their pressure on the system. Urgent steps are needed to protect the freedom of the universities from such unwanted interference. Any endeavour to introduce changes and reforms must have the fullest support and cooperation of all.

9. A major part of undergraduate teaching, and to a much lesser extent post-graduate teaching, is now conducted through the large number of colleges affiliated to the various universities. The standards at these colleges vary from the most depressing ones to reasonable ones. In improving this situation special attention needs to be given to colleges located in small towns.

10. The pressure of numbers can be eased to strengthening not only vocationalization at the +2 level but also at the undergraduate level. Since the pressure of numbers at the undergraduate level is not likely to go down, the possibility of two streams, one for general purpose (and vocatinalization) and the other for a career in science, with suitable syllabi and evaluation methods be considered.

11. University education should be primarily geared for post-graduate, doctoral and post-doctoral studies. If the burden of conducting examinations at the graduate level is removed from the universities, they can concentrate all their attention to higher education and research. If in colleges MSc teaching is to be continued, it must be made mandatory that there are adequate facilities for research in those subjects. There is a great need and scope for closer links between the universities and the R & D laboratories and industries. There are innumerable things that can be done without much additional resources to the benefit of both parties.

12. Administrative and management procedures currently in practice in the universities are not conductive to the promotion of quality teaching and research. Corrective steps are overdue.

13. Talent search schemes for students reaching the universities must be linked to assurance of appointment when they complete MSc or PhD degree and better emoluments during studies. This will provide fresh motivation to students and may minimise brain drain.

14. The UGC is operating a Special Assistance Programme to promote research in the universities under three categories : Departmental Research Support, Department of Special Assistance and Centre of Advanced Study. Work carried out under this programme must be subject to periodic peer evaluation. Good departments should be provided increased support so that they can become competitive in the international scientific scene. Objective evaluation is an essential ingredient for all excellence and quality; teaching and research in the universities must be subject to this.

15. Rotating headship of university departments was introduced in many universities hoping that it will improve the overall academic management of teaching and research. However, contrary to the expectation, it has not had the desirable effect. This practice, therefore, needs to be re-examined.

16. Teaching and research in professional courses like medicine and engineering have special problems; these have to be looked into and corrective steps taken.

17. We should not forget the supreme importance of the teacher. The teacher is irreplaceable. Not only should we impart good teacher training and retraining programmes, we should also find ways of rewarding excellence in teachers. A good teacher sows many seeds of excellence.

18. Journals of science education should continue to be supported. They should made readily available to students and teachers at all levels. All tools of modern educational technology should be employed to improve the quality of education and to promote scientific temper.

## Concluding Remarks

At this stage of debate in the country, we must concentrate more on major issues and not get caught in details and technicalities. At the next stage when the Government formulates its major objectives and strategies for implementation, a number of suitably constituted working groups and

task forces must be set up to work out the details. Any decision for urgent implementation without due analysis of problems and advance preparation may prove counter productive.

Changes in the objectives and goals of education and research will need new input of resources and a national will and determination for implementing the change. These should be assured in adequate measure.

The Indian National Science Academy and its Fellows comprising scientists from universities, national laboratories, and public and private industries, and representing all fields of science and engineering, will be most happy to assist in providing a new direction to higher learning and research in science and technology.

# Issues in Higher Science Education

C N R Rao*

## I. Introductory Comments

1. It is most heartening that the Academy is addressing itself to important issues related to higher science education in the country. The purpose is obviously not to list a whole bunch of problems and suggest a variety of solutions. It is mainly to underscore the seriousness of the situation, point out the alternatives and make meaningful recommendations of a priority nature. The discussion meeting is also timely since the country is now considering bringing about changes in the educational system. Furthermore, we are just 15 years from the 21st century.

2. There is already much written about higher science education in the country that probably there is little new that one can add. We have the well known report of the Education Commission (chaired by Prof D S Kothari, one of the distinguished past Presidents of the Academy) which has examined many issues and made several recommendations. I shall, therefore, limit myself to a few issues which I consider to be salient and not make my presentation all inclusive.

3. Higher science education today presents a rather discouraging picture. There are serious complaints at all levels about the lack of responsiveness in the system. Academic activities are at a low ebb. Several factors of a complex nature have contributed to the present condition. Some of the factors are related to processes and pressures in our society and therefore reflect the social features prevalent in a particular region. However, there are several other aspects where planners, adminstrators and teachers can do much.

## II. Some of the Important Issues and Problems

### (*a*) *Undergraduate education*

1. We cannot consider problems and challenges of higher education in science without reference to problems faced in school education. We

*President, Indian National Science Academy, New Delhi 110 002 and Director, Indian Institute of Science, Bangalore 560 012.

obviously need to re-examine science education at schools. There is no need to stuff our students with information on scientific subjects. Inculcation of scientific attitude in students is more important in the early school years, say up to 10th class, particularly because many of them may not turn out to be scientists. It is also important that we make sure that there is a proper vocational stream available at school level so that all students do not rush towards science and technical courses at college level. There is need to provide general science courses at lower levels and give specialised courses only in the higher (11th and 12th) classes.

In spite of many problems we are facing in science education, it must be admitted that many good students come out of our school system and a good percentage of them do extremely well in scientific and technical professions. By and large, one might even say that training, at least in some of the schools in the country, is quite adequate and is not much inferior to that in good schools elsewere. However, in a large majority of schools in the country, the quality of training and facilities are inadeqate and we have to bring their level up.

2. There is undue interference by too many forces in the planning, administration and management of universities. It is not due to the concerned Governments alone. Affiliated colleges have been given too much importance in managing universities; this can be eliminated by delinking undergraduate examinations from the universities. Universities should provide leadership in curriculum development, higher education at post-graduate level and research. Absence of a proper academic as well as administrative leadership, structure and practices (including indiscriminate rotation of department heads) have had damaging effect.

3. The common problems associated with undergraduate science education are well-known. Undergraduate science education is generally concentrated in colleges, many of which are under-equipped, over-crowded and poorly staffed. Laboratory and library facilities are generally inadequate; proper text books are not available. The level attained by a BA or BSc is very much inferior to that of a graduate in advanced countries. It is at the undergraduate level that we see this sudden gap in the quality of education. While there are some select centres where the quality of postgraduate education is quite good, similar undergraduate centres are not available for bright students, who want to take up science. There are, however, several good institutions in engineering and medicine.

4. Undergraduate curricula are rigid even in the best of places. Combinations such as PCM and CBZ do not provide the necessary breadth or depth. The absence of flexibility has made it impossible for a good student to obtain sound training. For example, a physics student can never

study biology just as a biology student can never study mathematics or physics. We have to make flexible programmes available, at least in some of the colleges.

5. It must be noted that all those taking science courses at the undergraduate level, are not necessarily going to be scientists. Most of them are going to be something else. It is, therefore, all the more important that we have at least two streams in science education; one of general purpose and another of specialised nature (for those who want to be scientists). The absence of such specialised training is making our undergraduate education not so meaningful and it does not compare with the training received in good institutions in the advanced countries.

6. Even undergraduate education in engineering has many problems and drawbacks, the most serious ones being the indiscriminate number of overcrowded and under-equipped colleges. The capitation fee system has had a bad effect on engineering education. The curricula as well as the laboratory facilities in a large number of engineering colleges are below par. The best of our engineering graduates go abroad or go for management and sales.

7. A specific deficiency in undergraduate instruction (both in science and engineering) is that related to computers and microprocessors. When the computer age has started all over the world (and even in India), our education system has not made a good beginning in this direction. Unless use of small computers is introduced, at least at undergraduate level if not at school level, our younger generation will face serious problems.

8. The most disturbing feature in our education system is that of examinations. While most undergraduate education is imparted in colleges, examinations are conducted by universities who have no direct interest or control in the educational process itself. We have to do something drastic to minimise the importance of examinations and increase the role of colleges in evaluation and examination. It appears as though much of the time of universities and teachers is spent in organising examinations and in declaring results. This is counter-productive.

9. In another 15–20 years, the student enrolement will get doubled. Can we even duplicate the present facilities (however poor)? Selectivity is obviously important.

We have to find ways of tapping the best telent available for science. Present efforts in this direction are by no means thorough.

(*b*) *Post-graduate education and research*

1. Many of the problems mentioned earlier with respect to undergraduate education also hold for post-graduate education. There are too many

institutions offering post-graduate education in science. Most of them are under-equipped and poorly staffed. I see no point in producing such a large number of MSc graduates. At the master's level, the number of people trained should have some relation to the national manpower requirements. We must have selective admission and selective recognition of institutions at least at the MSc level. It is often said that our MSc is not as good as a BA or BSc from the better universities of advanced countries. This has to be rectified if our training has to gain respect in the eyes of our own community and the rest of the world.

2. University departments are supposed to carry out research. Although some good work has come out of the universities, it would not be wrong to say that most university departments have poor infrastructure facilities. They are also short of highly qualified and motivated teachers. Now-a-days, research support to individual scientists is quite satisfactory. Some of the good departments are getting infrastructure support under the COSIST programme. However, the institutional infrastructure seems to be generally poor; shortage of student accommodation, amenities, poor electricity and water supply are common. Unless the universities have sufficient strength to support higher education and research, the support we may give individuals or departments would not yield maximum benefit. It is, therefore, important that universities get more basic bread and butter funding. A possible solution to this would be to give a good percentage (say, 40 to 50%) of the research support as overheads to universities. This has to be in addition to the budget already provided for research by the funding agencies, thus enabling our educational sector in getting some funding for science from the government. Otherwise, Plan budgets allocated for science in the educational sector are too meagre.

3. Post-graduate education is not attracting the best talent, the problem being especially severe in engineering. Engineering research in the education sector has suffered badly because of this. The 3-semester ME programme has affected research efforts of engineering faculty; possibility of thesis and non-thesis option ME degrees could be considered.

### III. Some Priority Recommendations

We can make a large number of recommendations but there would be nothing new in many of them. An obvious one would be to multiply our education budget. Many such recommedations would cost enormous money and it would be unrealistic to expect all of them to be accepted or executed. I think, therefore, that only priority recommendations and action points should be emphasised here and many of them should be within our reach. Some of the important recommendations may not require much money but rather our determination to improve the quality of education.

1. Admission to the science specialization stream should be made selective; students in the special stream must get the best possible science education. A general purpose degree with some science courses should be more than adequate for students going in for other professions. The selectivity could also occur at school level so that the number of stu dents in the science stream would become small, thus enabling colleges and universities to provide better education and to improve the available facilities. This is very crucial in view of the increasing number of colleges and students in the country.

2. A few model undergraduate science colleges or institutions should be started in each State to attract students for science just as IITs and Regional Engineering Colleges have been attracting students for engineering education. To start with, one such institution in each State could be instituted. The facilities and capabilities of certain major institutions (IITs, IISc etc.) could be made use of for the purpose. It is estimated that about Rs 5-6 crores (for 5 years) would be required for one such institution.

3. Universities should no longer be responsible to conduct undergraduate examinations. Individual colleges or groups of colleges should conduct examinations and give a certificate to the students. Although this may pose some difficulty in the initial stages, after a few years the situation will stabilise. Unless we do this, I cannot see how in another 15 or 20 years, when we would have double the student population of the present day, we can conduct examinations the way we are doing now. In order to calibrate performance, the university may like to give one or two tests in each subject. Students could take these examinations in addition to the college examinations in order to enable others to evaluate their performance in the undergraduate programme. This would mean that admissions to post-graduate instiutions as well as employment will have to be based on selection examinations conducted by each institution. rather than based on college performance alone.

4. (a) Text books in all subjects (at undergraduate level at least) should be made available to students. Colleges must have several copies of texts in the reserve sections of libraries.

(b) Computer facilities and formal training programmes in computing must be made available in each major town or city, if not in each college, so that youngsters can get adequate training. Such courses could be conducted during holidays and during off-hours to enable participation of a wider group of students.

5 There should be more recognition and support for the fabrication and production of local equipment and instruments.

6. In view of the exploding frontiers of knowledge, better ways of training and retraining teachers will have to be explored. Ways have to be found for attracting better scientists and engineers to the teaching profession. One possibility is to depute young graduates to advanced institutions here and abroad and get them trained in specific areas.

7. (a) Support to select departments under the CAS & DSA programmes of the UGC should be enhanced. It would be desirable to support research units of individual workers where necessary; this would be specially applicable to situations where the department itself may not be strong enough to get adequate support.

(b) Infrastructure of universities has to be improved greatly. Since there is no simple way of doing this other than by increasing the budget of universities, it is proposed that an additional source could be right away provided by encouraging funding agencies to grant a reasonable percentage (say 40–50 per cent) of the research grants as overheads. This would mean that those universities which carry out good research work can also get good support from the funding agencies. This would also act as a good incentive for carrying out research.

8. Project-oriented undergraduate instruction should be encouraged both in science and engineering colleges rather than stuffing students with bookish material. Such project-oriented education could be given to select students, if not to all students. This would become possible only if the undergraduate curriculum becomes flexible: this would also enable students to take a good mix of courses and eliminate the imbalance that we find now where physical or engineering scientists cannot take biological courses and vice versa.

Research, development and design, instrumentation etc. should be given proper academic recognition, if necessary by awarding appropriate degrees (e.g., Dr. Tech.).

9. We should intensify talent search in all parts of the country in order to ensure that the hidden, untapped talent is available to the country.

## IV. Concluding Remarks

It is clear that I have not mentioned all the issues or made all the important recommendations related to the improvement of higher science education. I hope, however, that some of the suggestions made here will be found worth-while.

Science has to find a proper place in our Society, if science education has to eventually make an impact in the country. This would mean that we have to pay more attention to inculcate the scientific attitude in our

people and in popularizing science. It would also be necessary to make scientific profession more attractive. This would be possible only if good professional opportunities are provided to capable young people who can be sure that they have a roof over their heads and other minimum comforts. They may then be more willing to take up challenging tasks involving science and engineering.

Everything possible should be done to see that universities become more academic both in their pursuits and in their managerial practices. Undue interference in academic matters and administration from external influences has to be minimized if universities have to become genuine places of learning.

The language problem has become a severe limitation in the learning process. There is little doubt that English is essential for higher science education. While students can study in schools in their mother tongue, it is important that they learn operational English (use of English language rather than literature). Large scale efforts should be made to teach English language by employing TV, Radio and other media to students and the general public.

I shall conclude this presentation with a word or two about the irreplaceable role of the teacher. A teacher's influence on his students lasts for a lifetime. The influence is not limited to scientific activities, but encompasses many aspects of life. This is important since excellence of a person manifests itself not merely in scientific research alone. The most durable influence of the teacher is not the substance of what is taught but in the manner of teaching. In fact, the most precious acquisition a student or a younger scientist gets may have little relation to the professional expertise of the teacher. What remains in the student's memory and in his character is the stamp of personality of the teacher rather than the repertoire of knowledge.

We take it for granted that a teacher must be a master of some subject. While that is an essential quality, it is not the criterion that has been reponsible for the lasting influence of many great teachers on their students. I would like to quote from a talk given by Lord Ashby :

> "The Chief quality that distinguishes a teacher is a determination and the skill to build bridges between two generations, to establish a lively communication with the young. The commitment of a teacher is not solely to transmit knowledge; it is to transmit a tradition of scholarship, an attitude to phenomena, a particular style of integrity".

The fruit of learning, after all, is not a book but a man. I strongly believe that this message has much to do with many of the issues that we are concerned about.

# Post-graduate Courses and Research in Science and Technology

M M Sharma*

Excellence in Science and Technology is not only essential for intellectual curiosity and satisfaction but also for economic prosperity. In all science-based industries, such as the electronic, nuclear, chemical and bio-chemical, important breakthroughs have come through pursuit of science at the highest level. We in India have an ancient tradition of creative thinking and subjecting new thoughts to probing and criticism by peers. We also have an unbelievably large reservoir of hidden outstanding talent.

Excellence in science has to be measured in the international context. Even excellence in technology ought to be seen in the international context although some protection, which is not desirable in long-term interest, can be provided through tariff barriers. Progress in different branches of science and technology has been phenomenal in the last two decades. This can be seen in everyday life, particularly in electronics and communications.

Systematic analysis in many developed countries has revealed that a high percentage of ideas of potential commercial relevance are still generated in small groups and not in large institutions. However, industrial exploitation of these ideas, often times through intermediate stages of pilot or proving plants, is very expensive and can only be undertaken by large companies and/or government support. There is a trend throughout the developed countries which makes them increasingly zealous and protective about their technology and unwilling to share their new technology even at high fees. These companies often ask for majority participation along with high royalty, in the joint ventures to exploit these new technologies. There is thus a clear need in India to have vigorous R & D activity as an instrument for rapid development in all spheres of our activities.

The role of universities is most crucial in this endeavour as research is really centered around individuals and groups and does not emanate only from an array of sophisticated and grotesque equipment. It is most

*Professor, University Department of Chemical Technology, Bombay 400 019.

unfortunate that in India this has not been duly recognised. We seem to have chosen a path where research is supported, intensively and extensively, in research institutions divorced from teaching or training element which is so very important. On the other hand universities are burdened by the problems of massive undergraduate college education.

University research is universally recognised as the most powerful and effective methodology to explore new ideas without fear and to train or develop bright young students. The young minds are uncontaminated and students do not have preconceived or prejudiced ideas and there is thus an openness in their approach. Since training and research activities are combined and students in this productive age group are eager to establish themselves quickly they work for protracted hours, even on holidays, with a zeal and commitment which hardly have parallels in purely research establishments or in industry. With proper leadership, university research can be buoyant and purposeful. It also an effective method of contribution to the general pool of scholarship and discovery.

The university system allows speculative, but well thought out ideas, to be pursued with a missionary zeal and we see the right sort of atmosphere for incubation of selected 'germs'. The regular turnover of bright students brings out a 'churning-effect' and there exists a healthy competition.

One of the great assets of the university system is that it can pursue original ideas to widen frontiers of knowledge without being buried under the garb of relevance. However, this does not imply that the university teachers have licence to pursue puerile ideas. The university system is an open-system and is always under surveillance by outsiders, and in any case, so far as research students are concerned, we are not stuck with the same individuals for protracted periods.

The foregoing attributes of university research may be labelled as lofty but these are at least potentially well placed. It is often said that practice in industry is always ahead of theory but it is conveniently forgotten that the art of practice can be sterile without linkages with theory. Thus there is the purely intellectual side, which must be vigorously nurtured, and the other side of practice. Perhaps, we in universities can find a 'window' and bridge this gulf albeit in a limited way.

Research thrives on ideas and prospers in a place with a continuing culture. We need an infatuous excitement and drive to take the innovative thoughts further. It is crucial to support unfettered research and encourage crystal gazing as long as quality of such endeavours is excellent. Further it needs to be emphasised that we cannot really plan truly original research; it arises from quality thoughts and often in a sporadic manner.

There is great merit in combining teaching and research rather than each of these being practiced in isolation. The training of students and quality of teaching undergo a sea of change when teachers have research back-up. Bright young students throw-up many questions which may superficially appear to be naive but sometimes turn-out to be original. The utility of the linkages between teaching and research has not received the attention it deserves. Teaching is usually a very challenging task, calling for clarity of thought, which is in any case a prime requirement for high quality research. Further, it forces the researcher to transmit thoughts to disbelieving students and to undertake wider reading. The presentation of thoughts in an orderly manner is greatly accentuated by teaching.

The intense international competition makes it imperative on our part to hasten the pace of scoring and we have to aim at hitting 'fours' and 'sixes' and not 'singles'.

The strengths of university research are widely accepted throughout the world. What then is wrong in our own context ? Why are we not so vocal about support for university research ? What do we give in return in tangible terms ? An attempt will be made to answer these and other pertinent points.

*Need for selectivity*

A highly selective approach is a must for postgraduate courses. All over the world, including the USSR and East European countries, it is recognised that admission to postgraduate courses must be highly selective whereas we have seriously erred in allowing mediocrity to percolate and in some cases dominate some of our courses. Research degrees must be only for those who have a penchant to pursue this career and who have demonstrated their intellectual and creative capabilities. Higher education at postgraduate level, of necessity, must be elitist.

*Need for revision of syllabi*

It is of the utmost importance that syllabi are regularly revised, say at intervals of 4 to 5 years since there are rapid changes in all branches of science and technology and it is essential that a system is introduced which allows changes to be made at frequent intervals. Thus in analytical chemistry, thanks to modern instrumentation, many species can now be analysed at parts per billion level accurately; even an eight year old syllabus gets out of context. Yet in many universities courses have not been revised for unusually long periods.

The procedures for revision of syllabus in most universities are archaic and, oddly, even staff members show reluctance under some ingenious

argument, presumably to avoid up-dating at their end. We must correct this situation.

*Need to guarantee rewarding careers for bright post-graduates*

Our post-graduates have only too often justified that after all their dedicated work they would not be able to find suitable jobs, even though our needs for scientific talent are very large. Careers for highly educated and talented students, who have come through a rigorous and long drawn screening system, need to be guaranteed. In scientific agencies there is an urgent need to abolish the single point entry system, with only MSc or BE as a requirement, as by very nature in S & T establishments complimentary staffing is a dire need and scientists must earn their next rank and not rise merely through bureaucratic procedures.

*Culture of research*

Research thrives in places which have a 'culture' which has to be nurtured for long periods. This requires a band of dedicated people and here lies the importance of 'schools of research' rather than grandoise institutions which do not have excellence in chosen areas of research. Apart from the culture of research we also need supporting administrative set-up to back-up PG courses and research. There is an urgent need to reform the administrative set-up in universities, particularly the older ones, which are saddled with affiliated colleges and have very poor appreciation for research work. Post-graduate departments must be serviced in an altogether different way than our present day practice. We also need performance audit.

*Selection of faculty members*

This is a crucial matter where we seem to flounder as a rule rather than as an exception. We have to ensure that our system attracts most talented persons. This implies that teachers have good salaries and the value system in the Society attaches importance to the role of teacher-researchers. It is well-known that many accomplished persons, who are not only very intelligent, but also have clarity of expression, although intrinsically interested in teaching and research, run away and gravitate towards other jobs in government or industry in view of attractive terms and conditions in these establishments. The rapidly changing nature of science demands flexibility in appointments whereas the system of recruitment in most universities has been made so tight, time-consuming and unresponsive to needs and relevance that even temporary appointments have become a nightmare. Would it be too much to expect some

radical changes and introduction of meaningful and purposeful procedures rather than secretarial oriented methodologies?

Careers in Teaching and Research have to be made far more rewarding than has been the case so far in our country. We have innumerable examples to cite from all over the world where teachers are by far the most highly paid individuals. After all we must recognise their 'reproductive' value.

*Need for up-to-date libraries*

An essential pre-requisite for post-graduate courses is a well-organised library which is open for extended hours. A malaise widely prevalent in our system is that libraries are neglected administratively and financially. We urgently need modern libraries complete with latest reprographic facilities which are open for at least 12 hours a day. It is not uncommon to find many departmental libraries which are effectively open only for six hours a day and subscription to relevant journals is very poor.

*Need for effective leadership*

Scientific research demands effective leadership but in defiance to this principle many universities follow the system of rotating heads and to make matters worse the tenure of the 'Head' is three years. With planned economy and the system of 'Five Year Plans' and need for perspective planning we do not see any purpose being served by the above strategy. We have experimented with this system for a sufficiently long time to come to the firm conclusion that this system has no merit. We should appoint heads on clear merit and at least for a period of five years. The same person should be continued if performance is found to be good. Many of our departments are suffering grievously due to this ill-conceived measure as this has systematically denuded them of leadership.

*Need for large number of seminars*

Our system of seminars needs sweeping changes to make them really effective. Cross-fertilisation of thoughts, spirit of enquiry, benefit of peers from different subjects, etc. greatly benefit through seminars. Post-graduate departments should designate one afternoon a week for this activity. Mini-seminars in smaller groups should also be encouraged. This will lead to systematic training of our students in presenting the subject matter in an orderly manner, be receptive to critisism, inculcate openness etc. Our seminars are taken casually and we teachers owe some responsibility in not making our system as effective as it ought to be.

*Need for funds*

The university system has been very poorly serviced. Even established schools, which enjoy world-wide recognition, have been poorly funded. Only in the recent past has some progress been made in providing larger support. There is an urgent need to drastically augment resources for the university system. Perhaps few people realise that more than 80% of our funds for research go to various agencies and very little percolates to the university system.

*Need for technical audit*

University teachers must be evaluated every year through a properly designed system. First of all teaching should be assessed by students as they are the most qualified persons to give grades. Clarity of thought, method of transmitting knowledge, ability to inspire young minds, etc. should find place in any evaluation system. Research work should be assessed from the point of view of originality of thought and its connection with developing young minds. We are not here in universities to train research students as glorified Laboratory Assistants who carry out work under daily instructions. Research students must be encouraged to publish independently. Unfortunately our score on this front is dismal.

*Concluding remarks*

The university post-graduate system can be buoyant, healthy and rewarding. There is a uniqueness in the system which has no parallels. We see highly motivated persons working with great vigour and rigour and we see tangible benefits of teaching and research being combined effectively under a single umbrella. We need to recognise publicly its great strength and relevance and accord the merited priority it so richly deserves. The university system has acquitted itself creditably even with all the difficulties widely prevalent in our country. Even our agencies have richly benefitted through the university system as a lot of their research work which has brought them laurels has been largely through Doctoral theses. We can tap this unbelievably large reservoir in universities imaginatively by providing the necessary support.

# On Higher Education in Science

P K Kaw*

Modern India is brimming with young people full of vitality, talent, enthusiasm and aspirations. This is our most precious resource. It is a fundamental right of these young people to go through an educational system which motivates them in the right direction, trains them and prepares them for the life to come and helps them in unfolding their potential to the utmost. It is our duty to provide them with such a system. Existing conditions are completely contrary to this. Our young people come out of universities as frustrated individuals who are disillusioned with their surroundings, fearful of the future and with no sense of direction. How do we put a stop to this ? Therein lies the challenge.

In what follows I shall restrict my attention to questions related to higher science education i.e. education at the Master's level of science and beyond. The first question one must address is what is higher science education meant for? I would like to answer this question in a non-traditional manner. I would restrict higher science education only to students who finally want to get into the creative activities like original research, research and development in laboratories of defence, industry, atomic energy, space etc. and to people who want to get into educational activities like teaching in universities etc. Persons with higher science education are a national asset. If they are smaller in number but properly trained, motivated and utilised, they can turn a country around especially in the modern world which is dominated by technology. Today India boasts of the third largest scientific and technological manpower in the world. But how many of us can really boast about the quality of this manpower or about the returns they have produced ?

What is it that ails our higher science education ? There seem to be two fundamental problem areas. First, there is lack of motivation and selectivity in the incoming student population and second, there is lack of proper facilities, proper faculty and proper training methods. We shall address the various issues one by one.

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*Physical Research Laboratory, Ahmedabad 380 009, India.

## I. Selectivity and Motivation

Who goes for science education today ? The dismal fact is that persons who do not get admissions in professional schools viz. medical and engineering schools gravitate towards higher science education—not because they are interested or motivated but because they must do something and they do not know what else they can do. The brighter ones out of these also appear in competitive examinations like IAS, banks and other secure professions. It is the distilled 'left over residue' which forms the major input to our higher science institutions.

This clearly presents two related problems. A large number of talented people today simply do not opt for a career in science because they do not see it as a rewarding career. At the same time a large number of unmotivated and uninterested students seek a career in science, but they are often not fit for it. Ideally one would like a situation where a large number of talented people are motivated naturally to seek a career in science and then one selectively chooses a small number viz. the ones who demonstrate a creative bent of mind so essential for higher science education.

### (A) *Selectivity*

A Stringent selection of incoming student population to higher science institutions is a necessity which cannot be overlooked. This is not only because this will considerably lighten the burden of our teaching institutions and enable them to improve the quality by greater attention to training of each student but also because higher science education must be reserved for those with a creative bent of min. Most students need not go for higher science education as they do not have the right aptitude. A majority of students in the science stream could in fact be siphoned off at the bachelor's level or even at the 10+2 level into vocational courses. There should be a large number of vocational training courses for a majority of science students to go into production oriented work related to electronics, computers, pharmaceuticals, industrial chemistry, oil exploration, agriculture, instrumentation, enterpreneurship etc. Industries can play a major role in organizing this sector by closely interacting with educational institutions and identifying areas of potential interest. Entrance to higher science institutions should thus be made highly competitive. It should be restricted to the chosen few who demonstrate competence in creative pursuits. On completion of their education and training, these are the young people who will lead creative efforts in various research groups, R & D labs of government, defence and industry, educational institutions etc. The actual numbers needed should also be determined by careful manpower planning. Finally, it must be emphasised that selection to the higher science stream should be entirely based on merit and innate

abilities. There is no room for reservations. Disadvantaged members of the society possessing talent and skills should be encouraged (at lower levels) by extra training, special courses, financial aids, scholarship etc. but must satisfy the same stringent criteria for admission which are applied to other students.

(B) *Motivation*

Let us now come to the question of motivation. How can one motivate bright young people into taking up a career in science ? Any person faced with a choice of the career will typically ask two questions : (a) is a career in science going to be sufficiently fulfilling as my life's work ? (b) is a career in science going to give me a comfortable life ? The first question is very important and we should not underestimate its value in moulding and influencing young minds. If our kids see our working scientists leading fulfilled lives with a high degree of job satisfaction, many of them will be motivated to take up careers in science; if not, even the motivated few will be repelled from such a choice. When our kids look at our working scientists they should not see people plodding away like cogs in a wheel, frustrated because they are not getting anywhere, indulging in escapism and ego-gratification in the form of frequent travel and foreign trips etc. They should see fulfilment of an honest variety resulting from solid contribution made to development of science, technology, defence, industry, education etc. within the country. They should see sparks of creativity in action; they should feel inspired by the dedication literally oozing out of such peers. In a country as large as ours, there are undoubtedly scientists who fit the above image. What is needed is an aggressive projection of right role models perhaps through media, perhaps through talks and seminars at colleges and so on. One needs to aggressively go out and convince young people that a scientist's career in India of today can indeed be challenging and fulfilling. Coming to the second question, (b) the degree of comfort and security in a scientific career has also to be made more attractive. In a rapidly changing society like ours, material aspirations of people are escalating rapidly. It is very difficult to depend only on the martyrs (viz. those highly motivated few who will do science no matter what) to man our scientific efforts. In the India of today there is nothing like the potential of a secure comfortable future, to attract bright young people to a career in science.

To sum up, one must make the scientific career sufficiently rewarding both in terms of its fulfilment and its security so that we can draw people from a broader talent pool than we are able to do today and then we should be merciless in our selection procedure and select only those creative few, who show appropriate aptitude for higher science.

## II. Training Component Improvements

This topic shall be divided into two subheads: (a) methods for attracting and maintaining excellence in teaching faculty and (b) improvements in teaching and examination methods.

(A) *Faculty improvement*

Excellence in higher science education can only be maintained if one has an excellent faculty for teaching bright young students. How can one attract and retain excellent faculty at institutions of higher learning? Definitely not with the present university structure. It simply repels excellence because it prevents the faculty from pursuing creative work. There are several reasons for this (i) university departments enjoy no autonomy (especially financial) so much so that even if a university professor is able to attract substantial research funds from some government agency after a careful peer review, he is often unable to utilise it because of interference by the centralised university administration; (ii) university has very limited resources of its own earmarked for creative pursuits; (iii) university professors are often burdened with undergraduate teaching to the extent that no time and energy are left for creative research. To top it all, in spite of all this active discouragement of creative research, one's promotion is often totally dependent on the number of research publications. The premium is thus on publishing a large number of papers, even though they are of a mediocre or poor quality. A university professor today is thus caught in a Catch 22; he is starved off research funds and resources and forced to publish indifferent quality work just to survive. This must change. University departments must enjoy financial autonomy; financial discipline can be ensured by issuing guidelines, random audit checks and black listing of individuals found guilty. Secondly, institutions of higher science teaching must be completely divorced from undergraduate teaching. Thirdly, universities must consider research as a very important component of higher science education and must demand more funds for it. It is vital for students at the higher science level to be immersed in an environment where learning and creativity are at a premium.

To improve the quality of teaching faculty, other methods can also be adopted. Teaching skills should be recognised and rewarded as such. There should be journals devoted to teaching methods, development of new teaching materials and teachers' conferences where teachers can exchange notes. There should be refresher courses where teachers can learn new areas which are constantly getting developed; at the end of such courses there should be an evaluation which should be tied to incentives and rewards. A teacher should thus be encouraged not to remain stagnant but to continue to develop.

(B) *Teaching improvement*

The training and examination methods that are in use today at most institutions of higher science learning in India are really archaic. No effort is made to emphasise the basic method and spirit of scientific enquiry. The emphasis is on learning by memory and then regurgitating at the examination time; there is no incentive to understand the subject matter.

It is really tragic that many of our science teachers, perhaps unwittingly often kill the spirit of scientific enquiry by their teaching methods. I would like to give two common examples to illustrate this point. One often comes across a situation where a particularly harassed and overburdened teacher, authoritatively shuts off simple (even superficial) enquiries from his students. This completely undermines the confidence of the student and subjects him to ridicule. It cannot be overemphasised that creative science progresses only by questioning. Questioning the basics is the heart of creativity. If we prevent our students from asking even superficial questions, how do we expect them to get the courage to ask deeper questions ? The deeper the question, the greater is the courage needed to ask it because one has to say that hundreds others who studied the topic earlier have missed something. The questioning spirit of our young minds is to be nurtured. We must teach our teachers to see that they do not kill this essential requirement of creative pursuit.

The second example has to do with teaching honesty and integrity in carrying out scientific work. I have come across examples (perhaps not atypical) where students working in a laboratory with a faulty apparatus have gone to the teacher with their not-so-accurate results and have been rebuffed and sent back and asked to get results 'as good as other students'. This encourages students to cheat, to cook the results. Thus, instead of teaching the student the scientific method which would examine the limitations of the apparatus and why the apparatus is giving 'wrong' answers and to appreciate these facts, the teacher in fact has forced the student to take a dishonest short cut completely contrary to the spirit of science. One has not only destroyed the student's ability to do that particular experiment but one has actually damaged his whole understanding of the spirit of scientific method. It is absolutely necessary that teachers who are responsible for teaching in higher science institutions have a very clear perception of scientific methods, spirit of enquiry essential for creative work, honesty and integrity necessary to follow inescapable questions, patience and skill to separate important questions from the unimportant ones and the ability and confidence to pursue a question in depth till an answer is found. It is my belief that more important than teaching the actual material and content of the books of science is to teach higher science students these crucial aspects of the scientific method.